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An Investigation On Ventilation and Air Conditioning (VAC) Installation, Design and Performances of Selected Buildings in Ilorin, Kwara State, Nigeria

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ABSTRACT
The need to maintain constant indoor thermal comfort for building occupants has been an interesting topic for a long time. Heating, ventilation and air-conditioning (HVAC) play an important role in providing a comfortable condition for occupants in a building. This work concerns air conditioning designs, installations, and performances of some event centres namely: Banquet Hall, Atlantic Event Centre and Nimatoni Event Centre and some offices within the Kwara State Ministry of Water Resources. The impact of the effect of improper design and ventilation on energy efficiency and consumption were also considered. The event centres and offices were studied, by taking both the temperature and relative humidity values for over a period ranging from 75 minutes to 130 minutes, with the use of a device referred to as HOBOware temperature/relative humidity data logger coupled with a HOBOware Software interface installed on a personal computer, for post processing of acquired data. The obtained results of the event centres showed variations in the capacities of the installed air-condition understudied. Also from the results obtained, the cubic meter per minute (cmm) values were found to be 0.0896, 0.2908 and 0.0404 for Banquet hall, Atlantic Event Centre and Nimatoni Event Centre respectively, and these were below the standard recommended value of 0.4245 in the literature.

Keywords: ***Air Conditioning, Hoboware Software, Ventilation***

1 INTRODUCTION

Ventilation and air conditioning (VAC) is a wide field with its system ranging from the simplest hand stroke mechanisms to the tremendously consistent overall VAC system found in submarines and space shuttles. According to Ariyo (1997), the climate of a place refers to the weather patterns that are normally observed in the place. This represents a set of variables influencing the cooling load of a building. The science and practice of creating a controlled climate indoor spacing is called Air Conditioning. The amount of energy which is required to cool a building climate depend on the building size and design, interior conditions which are maintained and type of equipment used. The specification of an appropriate thermal environment and tolerances depends on an adequate definition of activities which involves the understanding of the people carrying out the activities, the age, sex, clothing, eating and resting habits of the occupants of a space at a given point in time, knowledge of the energy requirements for their work and the customary indoor thermal experience is important. In hot weather, heat should be dissipated from the body to be comfortable and also to prevent body temperature from rising. Air therefore is the medium with which buildings are cooled and their occupants made comfortable. VAC systems moves conditioned air to dictated areas of an indoor environment creating and maintaining desirable temperature, humidity, ventilation and air purity. Based on building design, construction, and location; various types of interior climate control systems ensure that interior spaces are maintained at comfortable levels year-round (HVAC Assessment Handbook, 2013).

For the selected buildings in this research work, the level of discomfort is always easily noticed just few minutes after the commencement of events at the understudied events centres, where people normally resulted into manual (hand) fanning whenever events are going on despite the fact that the installed air conditioning unit are working. Therefore, the aim of this work is to investigate ventilation and air conditioning design and performance for those selected buildings, so as to know if they are in conformity with the specified standards in the literatures. The work attempted to (i) investigate Ventilation and Air Conditioning performances in the selected buildings; (ii) compare investigated results with existing standards; and (iii) redesign the VAC system for one of the event centers in accordance with existing standards for better thermal comfort.

2 MATERIALS AND METHODS

The following event centers and buildings in Ilorin, Kwara state, Nigeria were considered for this work: (i) Banquet hall, opposite Kwara State Government House; (ii) Atlantic Event Centre, Offa garage road; (iii) Nimatoni Event Centre, Unity/Irewolede Road; (iv) Ministry of Water Resources, Conference Room; (v) Ministry of Water Resources, Director WRES; (vi) Office of the Permanent Secretary, Ministry of Water Resources; and (vii) Office of the PFS, Ministry of Water Resources.

2.1 EXPERIMENTAL SETUP

The HOBO temp/RH logger shown in figure 1 which is automated to launch, analyze and process with the aid of operating software called HOBOware is employed for both temperature and relative humidity data acquisitions and analysis for the various event centres investigated. It was placed (i.e. 1m away from the VAC system) within the confinement of the event centres and public buildings under study for a total duration of 90 minutes for which the variation occurring between the temperature and relative humidity of the system was recorded at a sampling interval of 5 minutes. The data captured are mainly the temperature and relative humidity for the various ventilation systems and the air conditioning devices installed or operational within the premises understudied at the stipulated period.

Figure 1: A photograph of the HOBOware device used

The data recorded was accessed through the HOBOware pre-installed software on a laptop for further analysis and discussions. The pictorial view of one of the inspected buildings is shown in figure 2.

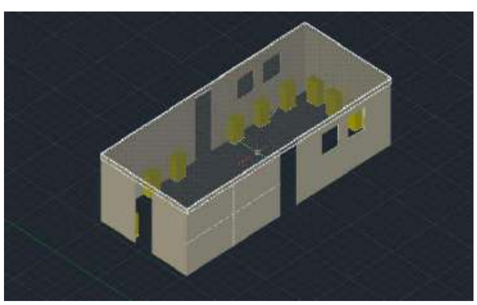

Figure 2: A pictorial view of the inspected building

2.2 DESIGN SPECIFICATION FOR AIR DISTRIBUTION

According to the ANSI/ASHRAE (American Society for Heating, Refrigerating and Air-Conditioning Engineers) Standard 62 (1999), the cubic meter per minute (CMM) which translates to the velocity at which air flows into or out of a space with respect to auditorium and theatre is 0.4245. To this end, the cooling load design parameters among other requirements are put into consideration to ascertain if the installed device were placed according to the standards of the overseeing bodies for Ventilation and Air Conditioning. In further analysis, the ventilation rate and air conditioning circulation in the system (i.e. the event centres under consideration) were ascertained based on the comparison with specified standards stipulated by the control bodies concerned with Ventilation and Air Conditioning across the globe.
Three basic factors under the types (sources) of heat generation were considered which equally helped to know the total capacity of the Ventilation and Air Condition that will effectively circulate the desired air distribution and flow for each of the chosen event center. The properties considered in this regard include: Hall (location and size), capacity, windows (number and type), door (number and type), wall type, location, illumination (number and capacity), ambient temperature and total or maximum occupancy. The aforementioned properties especially those that dealt with heat generation and transfer gave the insight for which our determination of compliance to standard was measured and scored. According to Heat transfer principle for cooling load regarding mechanical fittings, calculative specifications was undertaken to determine the confinement to standard by the selected public buildings (event centres and offices). This is further shown descriptively below:

2.2.1 DESIGN FOR LIGHT

The heat load from lighting within the building was determined from the sum total of the numbers of lights putting into consideration their types and wattage. The total wattage values with the usage factor and the special allowance factor shown below according to ASHRAE Fundamental 1997

$$Q = N\ x\ W\ x\ F_{UT}\ x\ F_{SA}\ x\ CLF \qquad (1)$$

Where, Q is the Heat Gained from Lighting Source
F_{UT} is the Lighting Use Factor
F_{SA} is the Special Ballast Allowance Factor
CLF is the Cooling Load Factor per hour of Occupancy
W is the Watt input from the Electrical
N is the Number of Light Type/Wattage

The wattage of light is based on the manufacturers reported value for the lamps in the lighting fixture without taking into consideration the ballast. The lighting factor is the ratio of the time the lights will be in use. The special allowance factor will take into description the heat from the ballast.
In respect to the Light usage, the Heat Gained Q for lighting at Atlantic Event Centre is calculated below:

$$Q = N\ x\ W\ x\ F_{UT}\ x\ F_{SA}\ x\ CLF$$

$$Q = 24\ x\ 85\ x\ 10\ x\ 0.1\ x\ 0.98$$

$Q = 1{,}999.2\ Ton$

2.2.2 DESIGN FOR ROOFS AND WALLS

The design specification follows the pattern and arrangement of a Tapoline design event centre as seen in Atlantic Event Centre. The Cooling Load Temperature Difference (CLTD) was the simplified approach employed for the determination of the heat load due to roofs and walls. In reality, their heat load has dependent factors and situations for which allowance was catered for in the design specifications.
Equation 3 was applied for the allowance and calculation for the heat load that existed in the roofs and walls of the event centre considered.

$$Heat\ gain, q = UA\ \nabla T \quad (2)$$

$$Q = U * A * (CLTD) \quad (3)$$

$$U = \frac{1}{R_{Concrete} + R_{Insulation}\ \ R_{Gypsum}} \quad (4)$$

q is the Heat Gained in Ton

A is the Area of the roof in m^2

U is the Thermal Transmittance for roof in Ton.m^2.°C

ΔT is the Temperature Difference in °C

Qr is the Cooling Load in Ton for Roof

Qw is the Cooling Load in Ton for Wall

U is the Coefficient of Heat Transfer for roof or wall or glass

A is the Area of roof or wall, m^2

Considering the heat generated from the roof and wall respectively in the confinement of Atlantic event centre with its area (60x25mx15m) and other values predetermined from ASHRAE Fundamentals, eqn. 3.3 employed.

Calculation for Roof:

$$Q_r = U * A * (CLTD) \quad (5)$$

$$Q_r = 0.35 * 900 * (8)$$

$$Q_r = 2{,}520\ Ton$$

Calculation for Wall:

$$Q_w = U * A * (CLTD) \quad (6)$$

$$Q_w = 0.2 * 1{,}500 * (21)$$

$$Q_w = 6{,}300\ Ton$$

2.2.3 DESIGN FOR PERSONS

The heat loads from an individual depends on the level of activity the person is involved in.

$$Q_{sensible} = N\ (Q_s)(CLF) \quad (7)$$

$$Q_{Latent} = N\ (Q_L) \quad (8)$$

Q_S is the Sensible Heat Gained

Q_L is the Latent Heat Gained

CLF is the Cooling Load Factor

N is the Number of Occupants

In calculating the heat generated and gained from people when Atlantic event centre having a capacity of 2,000 persons and other data picked from standard, certain assumptions stated below were made in accordance to the standards recommended by the regulatory bodies.

Assumptions:

i. Based on ASHRAE regulation, the sensible heat gain from persons is assumed 30% convection and 70% radiative.
ii. Solar Cooling Load (SCL) features are required in lieu of regulation to conduct temperature gains from glass.

$$Q_{sensible} = N\ (Q_s)(CLF) \quad (9)$$

$$Q_{sensible} = 2000\ (0.075)(0.99)$$

$$Q_{sensible} = 148.50\ Ton$$

$$Q_{Latent} = N\ (Q_L) \quad (10)$$

$$Q_{Latent} = 2000\ (0.035)$$

$$Q_{Latent} = 70\ Ton$$

2.3 ANALYSIS OF CALCULATED CUBIC METER PER MINUTE (CMM) PER PERSON

The redesign for Atlantic Event Centre is shown in the calculations below, specific information required were deduced from standard table attached as appendix. The determination of the value of the cubic meter per minute of the individual occupants of the event centre is calculated in accordance with standard specification.

$$CMM = \frac{Q\ x\ (hr.cmm.℃)\ x\ N}{hr\ x\ Av.T} \quad (11)$$

Q is the Heat gained from the installed A/Cs = 31 tons
N is the Number of installed A/Cs = 16
Av T is the Average Temperature = 28.43°C
Hr is the Hour = 60 mins

$$CMM = \frac{31\ x\ 16}{60\ x\ 28.43}$$

$$CMM = 0.2908$$

The calculations above showed that the CMM/person presently available in the understudied event centre (0.2908) is below the standard requirement of 0.4245. Due to this analysis, a redesign for the event centre was undertaken to determine the actual VAC system that will sufficiently satisfy the number of occupants for which the event centre was designed which is shown in the calculation below:

$$CMM = \frac{Q\ x\ N}{hr\ x\ Av.T}$$

Q = 31 ton

N is the No of VAC system = X

$$CMM = \frac{31\ x\ X}{60\ x\ 28.43}$$

$$0.4245 = \frac{31\ x\ X}{60\ x\ 28.43}$$

$$X = \frac{60\ x\ 28.43\ x\ 0.4245}{31}$$

$$X = \frac{724.1121}{31} \cong 23\ A/Cs$$

From the above calculation, the total heat gained will require twenty-three evenly spaced Air Conditioning System with eight (8) mirrored glass windows as presented in the Figure 3.2 against the existing structure at the event centre.

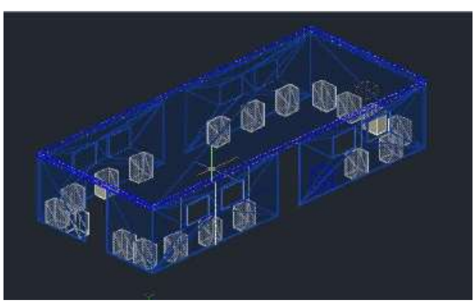

Figure 3: A pictorial view of the design according to Standard Specification

3 RESULTS AND DISCUSSION

3.1 Discussion on Banquet Hall

The specifications and rating of the various air conditioning systems operational in the Hall is shown in the Table 1.

Table 1: BANQUET HALL EQUIPMENT CHART

A/C Types	No (s)	Tonnage	Total Tonnage
L.G Split	6	2.25	13.50
Rest Point Split	10	3.38	33.75
L.G Split	10	10.00	100.00
Total			147.25

The tables 1, 2, and 3 respectively showed the total number of tonnage within the event centres as 147.25, 496 and 86.15 respectively. These values provide the total air capacity that circulates through the various centre considered in the course of the research work.
The results of temperature and relative humidity values of Banquet hall at stipulated time interval is graphically presented in Figure 4
The temperature of the hall decreases with an increase in the relative humidity. Information of note on the graphical representation of the derived reading shows that there were fluctuations in the readings gotten regarding relative humidity (a dependent factor on the temperature and pressure of a given system of interest). Temperature variation within the premises of the Hall in the course of carrying out the research readings which is due to the differing saturation rate and diffusion of air flow within the confinement.
The CMM value gotten for the hall was 0.0896 as against the standard 0.4245 allotted for theatres and auditorium. From the calculations, it was obvious that the VAC system provided was below the requirement for the space.

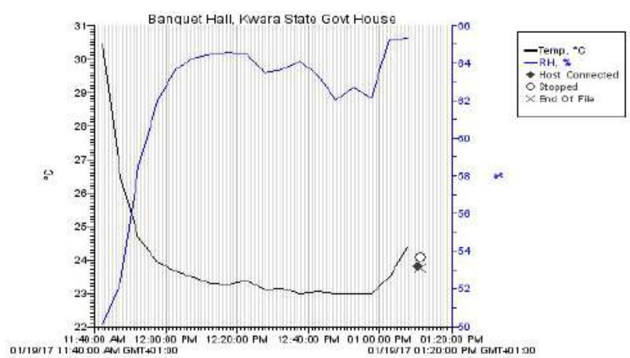

Figure 4: Banquet Hall Graphical Chart

3.2 Discussion on Atlantic Event Centre

The specifications and rating of the various air conditioning systems operational in the hall is shown in the Table 2 below.

Table 2: ATLANTIC EVENT CENTRE EQUIPMENT CHART

A/C Type	No (s)	Tonnage	Total Tonnage
L.G Industrial Duct	16	31	496

One important information that was noted about this event centre is the uniformity of the ventilation and air conditioning system that is been installed in the facility. Although there exist uniformity of arrangement for air conditioning system, the installed VAC within the premises were inadequate for effective cross ventilation and circulation of air distribution for the occupants of the space. Figure 5 shows the graphic presentation of the relative humidity and temperature readings for Atlantic Event Centre.

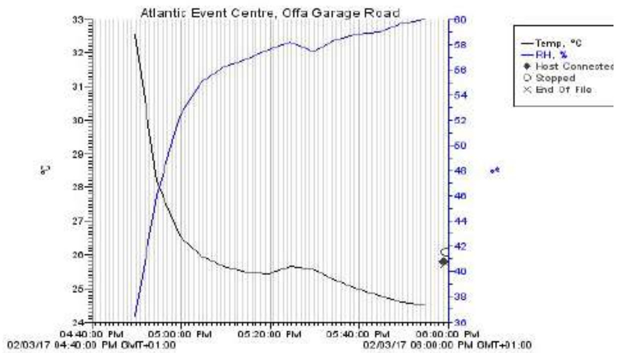

Figure 5: Atlantic Event Centre Graphical Chart

The results on the VAC system for Atlantic Event Centre were obtained through the HOBO device. Fluctuations in the readings were noted with respect to the relative humidity which is as a result of the human movement within the premises of the hall among other factors in the course of carrying out the research readings.

As seen above, there exist a significant relationship between the temperature and relative humidity curve. This is because increase in the relative humidity of the centre gave rise to a reduction in the temperature of the area which in turn leads to the proper coolness of the centre to aid a suitable environment for comfort. Graphical representation of the derived reading gave a pictorial view of the relative humidity (a dependent factor on the temperature and pressure of a given system of interest); simultaneously with the temperature variance within the premises of the centre in the course of carrying out the research readings which is due to the differing saturation rate and diffusion of air flow within the confinement.

Based on the calculated CMM per person obtained (0.2908 as against 0.4245); an upgraded design has been recommended as shown in Figure 2. It is of note that the VAC system in this event centre though duly arranged to allow for cross air distribution and flow is not sufficient for the capacity it has been designed to cater for.

3.3 Discussion on Nimatoni Event Centre

The specifications and rating of the various Ventilation and Air Conditioning systems installed for Human Comfort in the Hall is shown in the Table 3 below.

Table 3: NIMATONI EVENT CENTRE EQUIPMENT CHART

A/C Types	No (s)	Tonnage	Total Tonnage
Poly Star Split (Single Vent)	10	5.00	50.00
Samsung Split (Single Vent)	4	6.00	24.00
Poly Star Split (Double Vent)	1	10.00	10.00
Samsung Split	5	0.43	2.15
Total			86.15

3.3.1 Additional Ventilation System

One of the information gathered about this event centre is the distinct structural arrangements of the ventilation and air conditioning system that is installed in the facility with respect to the sitting positioning proposed for any event occupants. Another standard noted within the event premises is in the supportive distribution of air flow within the hall confinement which involves the inclusion of fans [Sixty two (62) ceiling fans and Seventeen (17) standing fans] to aid the circulation of air produced from the air conditioning system and further allow for effective cross ventilation of air for the occupants of the space at any given point in time.

The temperature/relative humidity variation record was taken by the device as shown in the graph presented in Figure 6

Figure 6: Nimatoni Event Centre Graphical Chart

Numerous and consistent fluctuations were noted in the readings with respect to the temperature and relative humidity alike; this is as a result of the constant human movement within the premises of the hall among other factors (most especially, power surge) in the course of carrying out the research readings.

It was obvious from the calculation that the VAC system provided was below the requirement for the space; the calculated cubic meter per minute (CMM) per person for the centre was 0.0404 which do not meet the comfort standard of 0.4245 CMM per person stipulated for auditoriums and theatres. It was discovered that even with the additional installation of stationary electrical fans suitably arranged to aid air distribution and flow of the ventilation systems and air conditioning devices within the building premises.

This research work which is an investigation on Ventilation and Air Conditioning (VAC) design and performances of selected public buildings equally considered a section of the Ministry of Water Resources, Ilorin. As listed above, the offices considered are: Office of the Permanent Secretary, Director (WRES & PFS) and the Conference Room. The capacity of the various offices are (2.25, 1.5, 1.5 and 3.0) Tons respectively. The Temperature – Relative Humidity ratio of the various offices were equally studied and recorded as it was in the case of the hall and event centre.

Figure 7 below shows the graphical representation for the reading recorded with the use of the HOBOware device for Ministry of Water Resources Conference room. From the readings and graphical representation, it was closely observed that after the drastic temperature fall that happened within the first five minutes of the device installation. Subsequently, there were sharp fluctuations in the temperature reading of the system noticed at intervals of twenty (20) minutes. This was concluded to be as a result of the time varying drop in the supply voltage of the air conditioning control system. The Relative Humidity of the room however, remained stable throughout the duration of the air flow reading record.

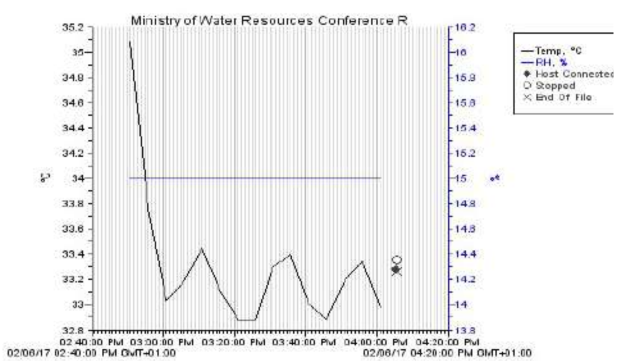

Figure 7: Ministry of Water Resources Conference Room Graphical Chart

The HOBOware was equally employed to determine the variation of airflow in the temperature and relative humidity of the Office of the Director, Water Resources and Engineering Services (WRES) with its graphical representation (Figure 8) below. The graphical representation for the reading recorded shows a sudden drop in temperature and a simultaneous quick rise in the relative humidity of the office. In continuity, there was a degree of constancy in the temperature and relative humidity of the system before a concurrent brisk increase in the temperature and relative humidity of the office.

To this end, the fitted ventilation and air conditioning device does not satisfy the standard condition for which it is been placed in use according to the requirement of the regulatory bodies.

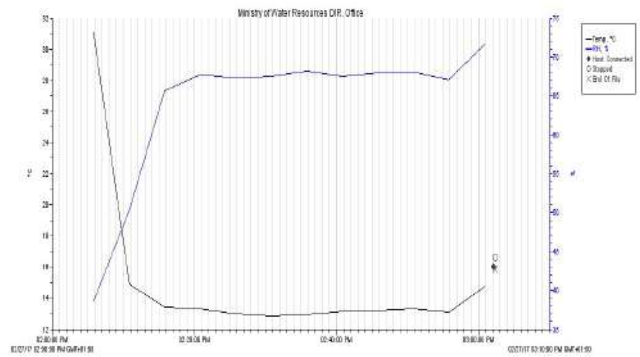

Figure 8: Ministry of Water Resources, Director (WRES)

The HOBOware device was used in measuring the variation of airflow in the temperature and relative humidity of the Office of the Permanent Secretary, Ministry of Water Resources with graphical representation shown in Figure 9 below. The graphical representation shows degree of constancy in the temperature of the system and a fluctuation in the relative humidity of the office. The steadiness of the temperature of the system after its sudden drop at the first interval was nonsynchronous to the relative humidity of the system.

The fitted ventilation and air conditioning device was noted to be lower than the recommended specifications and standard condition for the space with which it is been placed in use according to the requirement of the regulatory bodies.

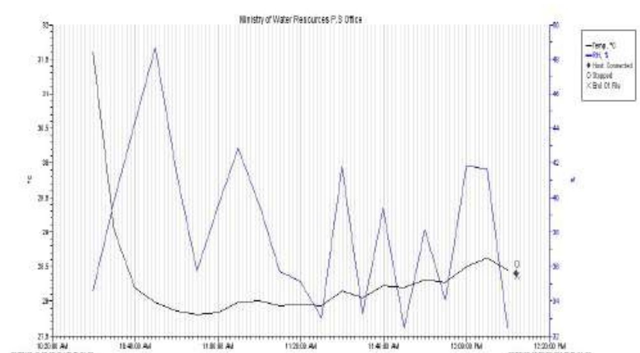

Figure 9: Ministry of Water Resources, Permanent Secretary' Office, Ilorin

The HOBOware device used in the measurement of the variation of airflow in the temperature and relative humidity for the Office of the Director, Personnel, Finance and Supply (PFS) has its graphical representation shown on Figure 10. The reading recorded show a concurrent degree of fluctuations between the temperature and the relative humidity of the system under study. There were signs of brisk reading which is shown in the graphical view at intervals of ten (10) and fifteen (15) minutes respectively. It is however of note that a sudden rise and fall occurred in the temperature reading recorded by the device which was equally noted in the readings of the relative humidity was as a result of the power surge that took place in the course of the research understudy within the office.

To this end, the fitted ventilation and air conditioning device does not conform to standard conditions according to the requirement of the regulatory bodies.

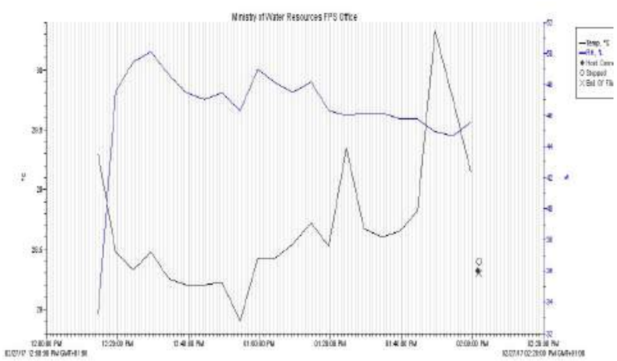

Figure 10: Ministry of Water Resources Graphical Chart

4 CONCLUSION

An Investigation on Ventilation and Air Conditioning (VAC) Design and Performances: Case Study of Selected Public Buildings (event centre and offices) in Ilorin, Kwara State, Nigeria has been carried out in this research work. From the above analysis of the event centre, it was noted that they were not well equipped and properly designed to suit their purposes. The design arrangement for the VAC system in banquet hall did not solely encourage and support effective and concurrent air flow and distribution within the studied enclosure. The air rating of the system due to their lack of equity equally contributes to the non-concurrency of the air distribution within the space of the hall. In the case of Atlantic Event Centre, the installed ventilation and air conditioning system were inadequate but equally and duly arranged within the confinement of the building and thus do not support quality airflow and distribution within the hall.

For the selected offices observed in the Ministry of Water Resources, one of the observations is that the installed ventilation system and air conditioning have capacities below the space and were equally not properly placed. Furthermore, the issue of the power rating for the various air conditioning devices are not been effectively managed as seen from the graphical representation derived from the tabular reading of the conference room. Conclusively, the research study has shown that most of the installed ventilation and air conditioning systems are below expected capacity in the various spaces for which they are employed, thereby giving rise to thermal discomfort which normally lead to hand fanning.

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